Physical Science Course Standards

Course Description

Physical Science is designed to serve as a foundation for other high school science courses. It is a laboratory course (minimum of 30 percent hands-on investigation) that integrates principles of chemistry and physics. It emphasizes inquiry-based learning, process skills, and higher-order thinking skills. Chemistry units include composition and classification of matter, atomic structure and the periodic table, and chemical bonds and reactions, together with basic nuclear chemistry. Physics units include forces and motion; conservation of energy, electricity and magnetism; and wave phenomena, characteristics, and behavior, including electromagnetic and sound waves. Because experimentation is the basis of science, laboratory investigations are an integral part of this course. Investigative, hands-on lab activities that address the high school inquiry standards are central to effective instruction in this course.

Standards in italics describe classroom learning that is essential for students to perform at a high level but that cannot be tested directly on a state assessment because of formatting, bias, technology, and sensitivity issues. However, these standards are appropriate for classroom assessment.

I. Inquiry

Inquiry is not an isolated unit of instruction and should be embedded throughout the content area of physical science. The nature of science and technology is incorporated within this area.

A. Identify Questions and Concepts That Guide Scientific Investigations

Experimental design should demonstrate logical connections between a knowledge base and conceptual understanding.

1. Demonstrate an understanding of the process of developing scientific hypotheses (e.g., formulate a testable hypothesis based on literature research and prior knowledge, select the correct form for a hypothesis statement based on a given scenario).
2. Identify and select experimental variables (independent and dependent) and devise methods for controlling relevant conditions.

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B. Design and Conduct Investigations

Science builds on prior knowledge; thus prior knowledge about major concepts, laboratory apparatus, laboratory techniques, and safety should be used in designing and conducting a scientific investigation.

1. Demonstrate an understanding of the process of testing scientific hypotheses (e.g., design and conduct a scientific investigation based on the major concepts in the area being studied).
2. Select and use appropriate instruments to make the observations necessary for the investigation, taking into consideration the limitations of the equipment.
3. Select the appropriate safety equipment needed to conduct an investigation (e.g., goggles, aprons) and identify safety precautions for the handling of materials and equipment used in an investigation.
4. Describe the proper response to emergency situations in the laboratory.
5. Identify possible sources of procedural error (e.g., incorrect measurement) and identify appropriate methods of control (e.g., repeated trials, systematic manipulation of variables) in an experimental design.
6. Organize and display data in useable and efficient formats, such as tables, graphs, maps, cross sections, and mathematical expressions.
7. Draw conclusions based on qualitative and/or quantitative data.
8. Discuss the impact of sources of error on experiments.
9. Communicate and defend the scientific thinking that has resulted in conclusions.

C. Use Technology and Mathematics to Improve Investigations and Communications

Scientific investigations can be improved through the use of technology and mathematics. While it is acknowledged that the System International of Units (called the SI system) is the accepted measurement system in science, opportunities to use the U.S. Customary System are encouraged where appropriate.

1. Select and use appropriate technologies (e.g., computers, calculators, calculator-based laboratories [CBLs], electronic balances, calipers) to achieve appropriate precision and accuracy of data collection, analysis, and display.
2. Discriminate between valid and questionable data.
3. Select and use mathematical formulas and calculations to express and interpret laboratory measurements.
4. Demonstrate an understanding of trends and patterns in data (e.g., calculate interpolated data points, predict extrapolated data points) and demonstrate the ability to interpret these phenomena.
5. *Draw a "best fit" curve through data points by using computer software and/or graphing calculators.*

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6. Calculate the slope of the curve and use correct units for the value of the slope for linear relationships.
7. Perform dimensional analysis calculations.
8. Perform calculations using numbers expressed in scientific notation.

D. Formulate and Revise Scientific Explanations and Models Using Logic and Evidence

Scientific explanations and models are developed and revised through discussion and debate.

1. Construct scientific explanations or models (physical, conceptual, and mathematical) by using discussion, debate, logic, and experimental evidence.
2. Develop explanations and models that demonstrate scientific integrity. (P)
3. Revise explanations or models.

E. Recognize and Analyze Alternative Explanations and Models

Scientific criteria are used to discriminate among plausible explanations.

1. Compare current scientific models with experimental results.
2. Select and defend, on the basis of scientific criteria, the most plausible explanation or model.

F. Communicate and Defend a Scientific Argument

Experimental processes, data, and conclusions are communicated in a clear and logical manner.

1. *Develop a set of laboratory instructions that someone else can follow.*
2. *Develop a presentation to communicate the process and the conclusion of a scientific investigation.*

G. Understandings about Scientific Inquiry

Historical and current scientific knowledge, current research, technology, mathematics, and logic form the basis for conducting investigations and drawing conclusions.

1. *Analyze how science and technology explain and predict relationships.*

    a. *Defend the idea that conceptual principles and knowledge guide scientific inquiry.*

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b. *Discuss how the available body of scientific knowledge, historical and current, influences the design, interpretation, and evaluations of investigations.*

2. Discuss the reasons why scientists and engineers conduct investigations and the methods they use to conduct these investigations.
3. Demonstrate and discuss the use of technology as a method of enhancing data collection and data manipulation and of advancing the fields of science and technology.
4. Discuss how mathematics is important to scientific inquiry.
5. Discuss why scientific models and explanations need to be based on the available body of scientific knowledge.
6. Demonstrate the understanding that scientific explanations must be logical, supported by the evidence, and open to revision.

II. Physical Science (Chemistry)

A. Structure of Atoms

1. **Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and the electrons holds the atom together.**

   a. Trace the historical development of the model of the atom, including the contributions of John Dalton, J. J. Thomson, Ernest Rutherford, and Neils Bohr. (H, N)
   b. Compare and contrast the component particles of the atom.

2. **The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons. When an element has atoms that differ in the number of neutrons, these atoms are called different isotopes of the element.**

   a. Trace the development of nuclear models including the contributions of Marie and Pierre Curie, Lise Meitner, and Enrico Fermi. (H, N)
   b. Identify the charge, component particles, and mass of the nucleus.
   c. Recognize that elements exist as isotopes, which may be stable or unstable (radioactive).
   d. Demonstrate the understanding that the number of protons identifies an element and is the same for all atoms of that element.

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3. **The nuclear forces that hold the nucleus of an atom together, at nuclear distances, are usually stronger than the electric forces that would make it fly apart. Nuclear reactions convert a fraction of the mass of interacting particles into energy, and they can release much greater amounts of energy than atomic interactions. Fission is the splitting of a large nucleus into smaller pieces. Fusion is the joining of two nuclei at extremely high temperature and pressure, and is the process responsible for the energy of the sun and other stars.**

   a. Compare and contrast fission and fusion reactions, showing how they are processes that convert matter to energy.
   b. Describe fusion as the process that fuels the sun and other stars.
   c. Demonstrate an understanding of the consequences of the development of nuclear applications such as the atomic bomb, nuclear power plants, and medical technologies. (P)

B. Structure and Properties of Matter

1. **Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element.**

   a. Determine the charge a representative element will acquire based on its outer electron arrangement.

2. **An element is composed of a single type of atom. When elements are listed in order according to the number of protons (called the atomic number), repeating patterns of physical and chemical properties identify families of elements with similar properties. This "Periodic Table" is a consequence of the repeating pattern of outermost electrons and their permitted energies.**

   a. Trace the historical development of the periodic table including the contribution of Dmitri Mendeleev. (H, N)
   b. Explain the arrangement of elements within a group on the periodic table based on similar physical and chemical properties.
   c. Explain that property trends on the periodic table are a function of the elements' atomic structures.
   d. Determine atomic number, mass number, the number of protons, the number of neutrons, and the number of electrons for given isotopes of elements using the periodic table.

3. **Bonds between atoms are created when electrons are paired up by being transferred or shared. A substance composed of a single kind of atom is called**

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an element. The atoms may be bonded together into molecules or crystalline solids. A compound is formed when two or more kinds of atoms bind together chemically.

a. Compare and contrast elements and compounds.
b. Classify compounds as being ionic or covalent on the basis of the transferring or sharing of outer electrons.
c. Determine the ratio by which elements combine to form ionic compounds and express that ratio in a chemical formula.

4. **The physical properties of a compound reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them.**

a. Relate the physical properties (e.g., boiling point, melting point, conductivity) of compounds to their ionic or covalent bonding.
b. Identify factors that affect the rates at which substances dissolve.
c. Compare the ratios of solute to solvent in concentrated and dilute solutions in relation to the physical properties of the solution (e.g., conductivity, melting point depression).
d. Analyze the behavior of polar and nonpolar substances in forming solutions.

5. **Solids, liquids, and gases differ in the distances and angles between molecules or atoms and therefore the energy that binds them together. In solids the structure is nearly rigid; in liquids molecules or atoms move around each other but do not move apart; and in gases molecules or atoms move almost independently of each other and are mostly far apart.**

a. Compare and contrast solids, liquids, and gases in terms of particle arrangement and the energy that binds them together.

6. **Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.**

a. Demonstrate an understanding of how carbon atoms bond to one another as simple hydrocarbons.
b. Describe the formation of polymers.
c. Discuss the importance of polymers as biological compounds such as proteins, carbohydrates, and lipids.
d. Determine the uses of polymers in everyday life.

C. Chemical Reactions

1. **Chemical reactions occur all around us, for example in health care, cooking, cosmetics, and automobiles. Complex chemical reactions involving carbon-based molecules take place constantly in every cell in our bodies.**

    a. Demonstrate an understanding of the process of rusting in terms of electron transfer (e.g., determine the number of electrons lost or gained, write and balance chemical equation for rusting, discuss the economic impact of rusting).
    b. Demonstrate an understanding of how metabolism is an inter-related collection of chemical reactions.

        1. Demonstrate the understanding that food is composed partially of large complex molecules that are broken down into simpler molecules. (P)
        2. Analyze how these simpler molecules are rearranged into new molecules within living things. (N)

    c. Explain the sources and environmental effects of some inorganic and organic toxic substances, such as heavy metals and PCBs. (P)

2. **Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog.**

    a. Investigate and provide evidence of a chemical change by recording systematic observations, such as change in color, odor, and temperature for various chemical reactions. (N)
    b. Recognize balanced chemical equations**.**
    c. Classify reactions as energy-absorbing (endothermic) or energy-releasing (exothermic) on the basis of temperature measurements.
    d. Conclude from experimental evidence, based on mass measurements, that mass is neither created nor destroyed during ordinary chemical reactions (e.g., balance simple synthesis and decomposition equations, conduct mass measurements before and after reactions). (N)

3. **A large number of important reactions involve the transfer of either electrons (oxidation/reduction) or hydrogen ions (acid/base reactions) between reaction ions, molecules, or atoms. In other reactions, chemical bonds are broken by heat or light to form very reactive radicals with electrons ready to form new bonds. Radical reactions control many processes such as the presence of ozone and**

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greenhouse gases in the atmosphere, burning and processing of fossil fuels, the formation of polymers, and explosions.

a. Differentiate between acids and bases.

1. Identify the physical and chemical characteristics of acids and bases, including their formulas, reactions with metals, and pH.
2. Determine the pH ranges and strengths of acidic, basic, and neutral solutions using appropriate instruments and indicators (e.g., pH meters, CBL probes, universal indicators).
3. Explain how acid rain is formed and discuss its effects on the environment. (P)
4. Demonstrate an understanding of the significance of pH as related to consumer products.

4. **Chemical reactions can take place in time periods ranging from the few femtoseconds (10–15 seconds) required for an atom to move a fraction of a chemical bond distance to geologic time scales of billions of years. Reaction rates depend on how often the reacting atoms and molecules encounter one another, on the temperature, and on the properties—including shape—of the reacting species. Catalysts, such as metal surfaces, accelerate chemical reactions. Chemical reactions in living systems are catalyzed by protein molecules called enzymes.**

a. Demonstrate an understanding of how reaction rates are a function of the collisions among particles (i.e., effects of temperature, particle size, stirring, concentration on reaction rates; and the effects of catalysts on reaction rates).

b. Apply reaction rate concepts to real-life applications such as food spoilage, storage of film and batteries, digestive aids, and catalytic converters. (P, T)

III. Physical Science (Physics)

A. Motions and Forces

1. **Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship F = ma, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.**

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a. Trace the historical development of the understanding of forces, including the contributions of Galileo, Isaac Newton, Benjamin Franklin, and Charles-Augustin de Coulomb. (H, N)
b. Predict the motion of an object in terms of Newton's first law (inertia).
c. Identify and investigate the factors that affect acceleration in terms of Newton's second law (F = ma).
d. Evaluate the effects of action/reaction in terms of Newton's third law.
e. Generate and interpret graphs of linear motion.
f. Cite examples of Newton's laws that are common in everyday life (e.g., using seat belts, diving from a boat, pushing a swing). (P, T)

2. **Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square of the distance between them.**

   a. Describe changes in gravitational attraction in terms of changes in distances between masses and in terms of changes in the masses.

3. **The electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel. The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square of the distance between them. Between any two charged particles, electric force is vastly greater than the gravitational force. Most observable forces such as those exerted by a coiled spring or friction may be traced to electric forces acting between atoms and molecules.**

   a. Demonstrate the interactions of like and unlike charges by examining changes in electrostatic attraction in terms of changes in distance between two point charges.
   b. Demonstrate an understanding of the production and effects of static electricity (e.g., its role in disruptions and damage to electrical devices, destruction of property and life, everyday annoyances such as static cling). (N, P, T)

4. **Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces. These effects help students to understand electric motors and generators.**

   a. Demonstrate an understanding of the relationship between electricity and magnetism (e.g., describe how moving electrical charges produce magnetic fields, describe how moving magnets produce electrical fields).

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b. *Examine the effects of the advent of electricity on individuals and society.* (H, N, P, T)

5. Analyze electrical circuits that obey Ohm's Law.

a. Demonstrate an understanding of simple series and parallel circuits (e.g., construct, compare, contrast, and schematically diagram simple series and parallel circuits).
b. Describe the meaning of voltage and amperage.
c. Perform calculations using Ohm's Law.
d. Explain how fuses, surge protectors, and breakers function. (T)

B. Conservation of Energy and the Increase in Disorder

1. The total energy of the universe is constant. Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. However, it can never be destroyed. As these transfers occur, the matter involved becomes steadily less ordered.

a. Analyze transformations between potential and kinetic energies.
b. Analyze transformations among other forms of energy such as heat, light, and sound, and mechanical, electrical, and chemical energy.
c. State and apply quantitative relationships among energy, work, power, and efficiency.
d. Understand and apply the principles of mechanical advantage (e.g., contrast the two forces and two distances that produce mechanical advantage when a machine is used to produce work).

2. All energy can be considered to be either kinetic energy, which is the energy of motion; potential energy, which depends on relative position; or energy contained by a field, such as electromagnetic waves.

a. Classify energy types as potential, kinetic, or electromagnetic.

3. Heat consists of random motion and the vibrations of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion.

a. Predict and measure the effects of varying the temperature, pressure, and volume of gases (e.g., balloon studies, the bends in divers, and the hazards of handling and storing pressurized gases. (N, P, T)
b. Describe particle motion and distance as the phase changes from liquid to solid to gas.

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4. **Everything tends to become less organized and less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. Examples are the transfer of energy from hotter to cooler objects by conduction, radiation, or convection and the warming of our surroundings when we burn fuels.**

    a. Demonstrate an understanding of the transfer of energy from hotter to cooler objects by conduction, radiation, and convection.
    b. *Compare and contrast the environmental impact of power plants that use fossil fuels, water, or nuclear energy to produce electricity.* (P, T)

C. Interactions of Energy and Matter

1. **Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter.**

    a. Identify and show relationships among wave characteristics such as velocity, period, frequency, amplitude, and wavelength using the formula $v = f\lambda$.
    b. Compare and contrast models of longitudinal waves (e.g., sound waves, seismic waves) and transverse waves (e.g., electromagnetic waves, water waves).
    c. Distinguish among the electromagnetic spectrum, seismic waves, water waves, and sound waves on the basis of their properties and behaviors.
    d. Demonstrate an understanding of factors affecting wave energy (wavelength, amplitude, and frequency) and its effects on everyday life (e.g., health issues, medical diagnostics and treatments).

2. **Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.**

    a. Compare and contrast the parts of the electromagnetic spectrum in terms of velocity, wavelength, frequency, and energy using the formula $v = f\lambda$.

3. **Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance.**

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a. Demonstrate an understanding of how the releasing of energy by electrons produces light (e.g., fireworks, neon lights, florescent lights, halogen lights).

4. **In some materials, such as metals, electrons flow easily, whereas in insulating materials such as glass they can hardly flow at all. Semiconducting materials have intermediate behavior. At low temperatures some materials become superconductors and offer no resistance to the flow of electrons.**

   a. Understand and compare the functions of insulators, conductors, and semiconductors.
   b. Evaluate the impact of the miniaturization of electric circuits upon individuals and society. (H, P, T)

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